PB81-234031

Tissue Assays and Population Characteristics of Roosevelt Hot Springs' Animals (1977-1978)

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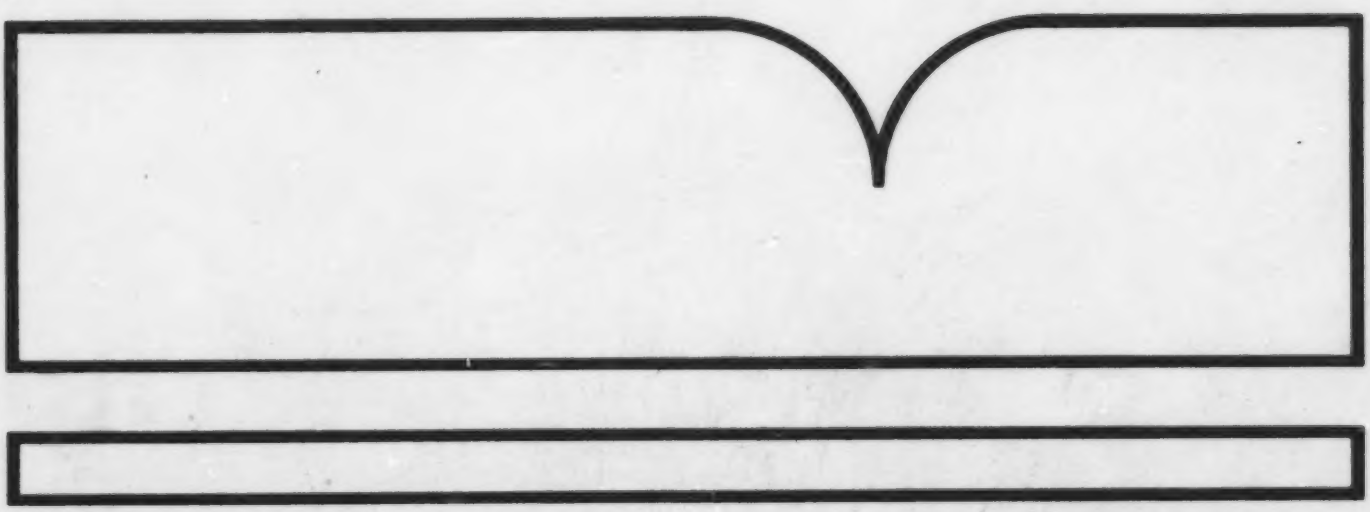
Las Vegas, NV

Aug 81



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1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-600/4-81-072	ORD Report	PB81 234031

4. TITLE AND SUBTITLE	5. REPORT DATE
TISSUE ASSAYS AND POPULATION CHARACTERISTICS OF ROOSEVELT HOT SPRINGS' ANIMALS (1977-1978)	August 1981
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Z. C. Nelson and W. W. Sutton	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Environmental Monitoring Systems Laboratory Office of Research and Development U.S. Environmental Protection Agency Las Vegas, Nevada 89114	1NE827
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
U.S. Environmental Protection Agency--Las Vegas, NV Office of Research and Development Environmental Monitoring Systems Laboratory Las Vegas, NV 89114	Project Report
	14. SPONSORING AGENCY CODE EPA/600/07

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Geothermal energy exploration is being conducted at several locations in the United States including a site at Roosevelt Hot Springs in southwest Utah. To assess any possible impact and to help design a monitoring strategy for geothermal development, element concentrations in animal tissues and selected animal population characteristics were determined at Roosevelt Hot Springs for the 1977-1978 period. The information can be used as baseline data as it was collected before any extensive industrial development had taken place.

Concentrations of barium, boron, cadmium, chromium, copper, iron, lead, manganese, strontium and zinc were determined for livestock and wildlife samples. In some cases, concentration values for additional elements (e.g., arsenic, lithium, magnesium, potassium and sodium) were also established. Small mammal populations (primarily rodents and lagamorphs) were also characterized as part of the effort to conduct baseline surveys prior to extensive geothermal development. Objectives of the limited population survey were to present information on habitat associations and species diversity as well as to provide an estimate of animal abundance both adjacent to and distant from the KGRA (Known Geothermal Resource Area).

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	48
	20. SECURITY CLASS *(This page)*	22. PRICE
	UNCLASSIFIED	

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

P881-234031

EPA-600/4-81-072
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TISSUE ASSAYS AND POPULATION CHARACTERISTICS OF ROOSEVELT HOT SPRINGS' ANIMALS (1977-1978)

by

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INTRODUCTION

The encouraging ecological feature of geothermal energy is that it is basically a contained system. The effluent rises to a heat exchanger and, in many cases, would be reinjected down a second well without exit to the surface atmosphere. Environmental damage therefore should be slight. Nonetheless, trace amounts of toxic elements frequently precipitate out of steam condensates and under some conditions might be transported to surface waters or dispersed as aerosols. The effect of geothermal development on area animal life is largely unknown. The delicate nature that comprises a native environment can be altered by changes in the elemental flow through an ecosystem, by distruction of habitats, human presence and activity, etc. (Berman, 1975). To assess any possible impact and to help design a monitoring strategy for geothermal development, element concentrations in animal tissues and selected animal population characteristics were determined at Roosevelt Hot Springs for the 1977-1978 period. The information can be used as baseline data as it was collected before any extensive industrial development had taken place.

Roosevelt Hot Springs is in southwest Utah on land managed largely for grazing cattle and sheep, although on irrigated acreage, at considerable distances from the geothermal resource activity, alfalfa, corn, potatoes and cereal crops are produced. There are also some dairy associations in the Minersville area. Water availability for range animals is a problem and some grazing allotments must have additional water delivered.

The 40-square-mile geothermal development site ranges in elevation from about 5,200 to 7,700 feet northeast of Milford on the western side of the Mineral Mountain Range. These mountains, extending in a north-south direction, not only are the dominant geographic feature but also have an obvious effect on the watershed and climatic conditions within the study area. Sloping foothills west of the mountains extend out toward the relatively flat Escalante Desert. Geothermal development at Roosevelt Hot Springs was in an exploratory state during the time of this study. Some test wells had been drilled but no power plants had been constructed.

Concentrations of barium, boron, cadmium, chromium, copper, iron, lead, manganese, strontium and zinc were determined for livestock and wildlife samples. In some cases, concentration values for additional elements (e.g., arsenic, lithium, magnesium, potassium and sodium) were also established. Small mammal populations (primarily rodents and lagomorphs) were also characterized as part of the effort to conduct baseline surveys prior to extensive geothermal development. Most rodents are relatively short-lived, have a high reproduction potential and, because of numerous litters, populations react promptly to either favorable or unfavorable environmental

conditions. Populations of hares and rabbits are subject to great fluctuations characterized by periods of high fertility eventually followed by an increase in the occurrence of predators, disease, and parasites. While these lagomorph cycles are repetitive, they do not occur at easily predicted intervals.

Objectives of the limited population survey were primarily to present some information on habitat associations, species diversity and some estimates of animal abundance both adjacent to and distant from the KGRA (Known Geothermal Resource Area). No effort was made to estimate potential changes in the occurrence or transmission of pathogens, changes in parasitic infection or potential hazards to long-term reproductive success. Vegetative communities mentioned as part of the current study area were grossly identified by the prominent plant species which included: (1) big sagebrush (Artemesia tridentata); (2) pinyon-juniper (Pinus edulis and Juniperus osteosperma); (3) big sagebrush/pinyon-juniper transition zones; (4) wash communities consisting mostly of big sagebrush and rabbitbrush (Chrysothamnus nauseosus); and (5) a small restricted greasewood community (Sarcobatus vermimlatus).

TRACE ELEMENT PROCEDURES

Blacktailed jackrabbits (Lepus californicus), range cattle (Herford), range sheep (Rambouillet-Columbia), Great Basin pocket mice (Perognathus parvus), deer mice (Peromyscus maniculatus), pinyon mice (Peromyscus truei), Ord's kangaroo rat (Dipodomys ordii) and western harvest mice (Reithrodontomys megalotis) were the primary animals used for this baseline study on trace element concentrations. Samples of hair/wool and blood from sheep and cattle were made in the spring and fall, seasons that coincided with the roundup and movement of animals between winter and summer ranges. Rodents were collected in museum special snap traps, and roadside kills were taken in the case of rabbit collections. Tissue or organs taken from the wildlife species included lung, hair, liver, kidney, and in some cases blood and bone.

For cattle and sheep, hair or wool was clipped from the animal's side and sealed in polyethylene bags. Blood samples were collected by jugular venipuncture in heparinized syringes or in heparinized vacutainer tubes and wildlife carcasses were sealed in polyethylene bags. All samples were transported back to Las Vegas in ice-filled cooler chests.

Muscle and fat were scraped from the bone samples and the hair samples were cleaned by the method of Clarke and Wilson (1974). Surface contamination was removed by washing the hair in separate solutions of soap, acetone, and ethylene-diaminetetraacetic acid (EDTA). Wet weights were recorded for all sample types and the collected material was either freeze-dried (blood and some rabbit tissues) or oven-dried (rodent tissue, all hair and bone samples) at 60°C. Dry weights were recorded and the individual samples transferred to acid washed polyethylene vials and stored under refrigerated conditions. The dried samples were subsequently ground with a cryogenic mill or manually mixed

with a teflon spatula or an agate mortar and pestle. All laboratory ware, mostly polyethylene, was washed with dilute nitric acid followed by a deionized water wash. Stainless steel, polyethylene and teflon spatulas, surgical instruments, etc. were cleaned in a similar fashion.

All assays were performed using either DC arc optical emission spectroscopy or flame atomic absorption spectrophotometry. Because of its simultaneous multi-element capability, optical emission spectroscopy was used for most of the determinations.* A cryogenic Tekmar mill (stainless steel chamber and carbide cutting blades) was used to produce a homogeneous sample for analysis. Dried tissue (National Bureau of Standards) of known elemental concentrations was also analyzed as part of the quality control procedures. Furthermore, a respective collection of blood and liver were freeze-dried and stored for repeated assays throughout the study period. The Laboratory of Nuclear Medicine and Radiation Biology, UCLA, conducted three separate analyses on all samples and standards.

For the atomic absorption assays, the samples needed to be in solution form. The initial nitric acid digestions conducted for this study were time consuming and, therefore, a commercial microwave oven was adapted (Abu-Samra et al., 1975) as a faster alternative. Oven adaptations included an internal pyrex liner, exhaust openings at the rear of the oven and an attached scrubber and exhaust fan to control the acid fumes. Flasks and beakers used during the microwave digestion were all made of teflon or of a high-grade borosilicate glass. The sample size did not exceed 1 gram dry weight or, in the case of whole blood, did not exceed 5 grams wet weight. Nitric acid additions were approximately 10 ml per 0.5 gram of dry tissue or per 2.5 grams of whole blood.

Standard quality control solutions (EPA-Cincinnati) were used which contained 15 elements at µg/l concentrations. A few samples were also spiked at different concentrations after sample digestion so that an analytical recovery estimate could be made.

Appendix A provides a detailed outline of the sample preparation procedures used for element analysis by atomic absorption spectroscopy. Sample preparation steps used for analysis by optical emission spectroscopy are given in Appendix B.

CENSUS PROCEDURES

The relative abundance of lagomorphs was determined through nighttime observations, and all rabbits and hares visible from the road by spotlight

*The relative standard deviation of this analytical procedure had been reported at between 3 and 15 percent for finely ground material with acceptable accuracy above 1 µg/g for most elements (Alexander et al., 1975).

were recorded. These data are presented as actual counts per kilometer travelled.

Values on relative abundance and species composition for the Roosevelt Hot Springs rodents were based on trapping information acquired during the spring and summer months. Parallel census lines and a grid trapping pattern (Smith et al., 1975) were both used at Roosevelt Hot Springs as part of the baseline characterization effort during 1977 and 1978. Two grids (separated by approximately 9 kilometers) were placed in the geographically prevalent sagebrush community. One of these grids (Grid I) was located adjacent to a geothermal test well near the center of the KGRA, and the other grid (Grid II) served as a modified control and was positioned in an area outside that planned for geothermal development. Each grid contained 100 trap stations* arranged in a 10 x 10 pattern. Live traps, baited with rolled oats, were placed singly at each station. Individual trapping periods were for at least three consecutive days.

The other major collection technique made use of parallel census lines. These lines (240 meters long) were placed 50 meters apart with each line containing 25 live traps at 10-meter intervals. Two sets of parallel trap lines (total of 100 traps) were placed at each selected location. In addition to these two major collection procedures, both live and snap traps were used throughout the study area (satellite trapping) to ensure that a collection attempt had been made at all plant associations within the KGRA. These traps were placed in somewhat of a random pattern but were usually 15 meters apart and had two traps per station.

Biomass estimations were calculated by multiplying the species density times the mean body weight (Nichols et al., 1975). Animal density was determined by dividing the relative abundance (Hayne, 1949) by the effective trapping area (Smith et al., 1975). The effective trapping area consisted of the grid plus a border zone added to the grid edge. Dimensions of this border area were calculated for each species. Border zones for deer mice and Great Basin pocket mice were based on average daily movement (Brant, 1962). The radius of home range was used as the border area for Ord's kangaroo rat. This species was not found at Roosevelt Hot Springs in sufficient numbers to establish daily movement. Species diversity, basically a ratio of the number of species and the number of individuals, was also used as part of the Roosevelt Hot Springs baseline characterization (Pielou, 1966; Lloyd et al., 1968). Furthermore, an index of similarity (Meullen-Dombois and Ellenberg, 1974) was included which allowed for some comparisons between communities based on the presence or absence of different species.

TISSUE ASSAYS

Tissues collected from Roosevelt Hot Springs mammals were analyzed for barium, boron, cadmium, chromium, copper, iron, lead, lithium, magnesium,

*Trap stations were separated by 15 meters. Each station consisted of a wooden marker stake and a single live trap.

manganese, potassium, sodium, strontium, zinc and, in a few cases, arsenic. Respective concentrations of these elements (presented as micrograms of element per gram of tissue) are given for range cattle (Table I), range sheep (Table II), jackrabbits (Tables III and IV), deer mice (Tables V and VI), Great Basin pocket mice (Tables VII and VIII), pinyon mice (Tables IX and X), Ord's kangaroo rat (Tables XI and XII) and western harvest mice (Tables XIII and XIV).

TABLE I. ELEMENT CONCENTRATIONS IN BLOOD, HAIR AND KIDNEY OF ROOSEVELT HOT SPRINGS CATTLE (Values are given in µg/g wet weight for whole blood and kidney samples and in µg/g dry weight for hair. Coefficient of variation is expressed as a percentage of the mean.)

	Whole Blood (n = 23)*				Hair (n = 24)*				Kidney (n = 7)**			
	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.
Barium	0.1	0.0	0.1	53.9	6.5	2.5	8.8	38.5	0.1	0.1	0.4	97.5
Boron	0.5	0.2	0.7	43.3	0.1	0.2	0.5	105.0	0.8	1.5	4.2	193.8
Cadmium	0.0	-	-	-	1.1	1.3	3.4	118.5	1.1	1.4	4.0	123.0
Chromium	0.0	-	-	-	1.6	1.3	5.2	83.6	0.1	0.1	2.0	80.5
Copper	1.1	0.1	0.5	12.2	5.6	1.3	6.0	22.6	16.2	9.0	27.0	55.4
Iron	491.5	82.1	225.4	16.7	60.3	70.7	333.3	117.3	120.9	42.2	122.9	35.0
Lead	0.0	-	-	-	2.4	1.0	5.2	43.1	1.8	1.6	4.5	91.6
Lithium	0.1	0.1	0.2	50.7	0.9	0.5	1.6	52.9	0.2	0.3	0.7	132.3
Magnesium	23.7	3.1	12.7	22.8	332.8	125.3	492.2	37.7	211.8	85.8	271.7	40.6
Manganese	0.0	-	-	-	13.6	6.5	25.6	47.8	1.5	0.7	2.0	44.5
Potassium	268.7	82.3	307.0	30.6	193.2	51.1	224.6	26.4	3,440.1	2,535.9	7,872.7	73.7
Sodium	4,142.9	100.4	198.5	22.7	331.0	136.6	586.0	41.3	4,869.8	3,154.0	8,929.5	64.8
Strontium	0.1	0.1	0.3	59.6	33.6	18.5	62.4	55.2	0.5	0.7	2.1	140.2
Zinc	4.3	1.2	3.5	26.8	26.1	7.8	27.5	30.0	18.9	9.9	29.9	52.2

* Blood and hair collections were from range cattle (Hereford) that graze in the general vicinity of Roosevelt Hot Springs for approximately six months per year.

** Kidney samples were from dairy cows (Holstein) which had grazed throughout the year on land approximately 50 miles east of Roosevelt Hot Springs.

TABLE II. ELEMENT CONCENTRATIONS IN BLOOD AND WOOL OF RANGE SHEEP (Rambouillet-Columbia) THAT GRAZE IN GENERAL VICINITY OF ROOSEVELT HOT SPRINGS APPROXIMATELY SIX MONTHS PER YEAR (Values are given in µg/g wet weight for whole blood and in µg/g dry weight for wool. Coefficient of variation is expressed as a percentage of the mean.)

	Whole Blood (n = 27)				Wool (n = 42)			
	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.
Barium	0.1	0.1	0.1	72.1	1.2	2.0	11.0	161.4
Boron	0.3	0.2	0.5	58.1	0.8	0.9	0.2	90.8
Cadmium	0.0	-	-	-	0.9	1.8	6.1	206.0
Chromium	0.0	-	-	-	0.9	1.3	5.9	145.5
Copper	1.3	0.3	1.2	22.9	3.5	1.2	5.1	55.2
Iron	521.5	117.6	431.1	22.5	45.9	41.2	185.5	39.7
Lead	0.0	-	-	-	0.5	0.6	1.6	122.6
Lithium	0.2	0.1	0.3	57.3	3.6	3.4	10.0	94.2
Magnesium	34.2	5.6	17.7	16.4	108.6	59.9	299.9	107.6
Manganese	0.0	-	-	-	0.8	1.0	4.2	35.3
Potassium	80.6	37.2	142.1	46.2	94.0	101.1	492.4	39.2
Sodium	409.5	49.0	209.2	11.9	255.3	110.1	434.2	43.1
Strontium	0.1	0.1	0.2	145.2	2.2	3.0	14.4	140.7
Zinc	4.6	1.8	6.8	38.9	28.1	11.1	50.3	87.6

TABLE III. ELEMENT CONCENTRATIONS IN LIVER, KIDNEY AND WHOLE BODY EMBRYOS OF THE BLACKTAILED JACKRABBIT (Lepus californicus) COLLECTED AT ROOSEVELT HOT SPRINGS (Values are given in µg/g wet weight. Coefficient of variation is expressed as a percentage of the mean.)

	Liver (n = 36)				Kidney (n = 35)				Embryo (n = 14)			
	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.
Barium	0.2	0.2	0.7	98.8	0.4	0.5	2.2	103.8	0.1	0.0	0.1	77.4
Boron	0.4	0.4	2.1	92.7	0.8	0.8	2.9	100.3	0.5	0.1	0.5	25.8
Cadmium	1.2	0.6	3.8	50.3	1.0	0.7	3.2	68.4	0.1	0.1	0.3	122.9
Chromium	0.1	0.1	0.3	160.0	0.1	0.2	0.9	196.5	-	-	-	-
Copper	13.0	5.0	26.1	38.8	9.4	6.3	28.2	66.5	4.3	1.6	4.9	37.7
Iron	243.0	169.8	667.1	69.9	117.8	60.2	226.2	51.1	55.1	12.1	37.9	21.9
Lithium	0.4	0.3	1.1	78.1	0.5	0.2	1.0	45.0	0.1	0.1	0.2	58.0
Magnesium	227.7	54.3	207.1	23.8	240.3	74.3	371.1	30.9	185.2	30.6	89.5	16.5
Manganese	3.2	1.1	5.2	34.5	2.5	1.2	6.8	48.5	0.4	0.2	0.7	48.1
Potassium	2,857.9	926.7	4,950.3	32.4	2,782.5	963.9	5,276.0	34.6	1,096.7	201.0	603.0	18.3
Sodium	1,632.1	530.1	2,131.5	32.5	2,637.3	758.9	3,374.7	28.8	3,519.2	341.0	1,376.2	9.7
Strontium	0.6	0.5	2.7	95.5	1.0	0.8	3.9	83.7	0.7	0.1	0.4	22.1
Zinc	31.4	9.0	41.3	28.6	18.1	8.8	47.6	48.7	12.7	3.9	12.4	31.1

TABLE IV. ELEMENT CONCENTRATIONS IN LUNG AND HAIR OF THE BLACKTAILED JACKRABBIT (Lepus californicus) COLLECTED AT ROOSEVELT HOT SPRINGS (Values are given in µg/g wet weight for lung and in µg/g dry weight for hair. Coefficient of variation is expressed as a percentage of the mean.)

	Lung (n = 28)				Hair (n = 34)			
	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.
Barium	0.1	0.1	0.6	71.1	5.6	9.8	51.8	176.1
Boron	0.3	0.2	1.0	60.8	2.9	4.2	20.9	142.3
Cadmium	0.5	0.4	1.1	86.4	0.4	1.4	5.0	326.9
Chromium	0.1	0.5	3.9	425.9	3.2	7.8	45.1	239.7
Copper	2.7	2.5	13.0	91.6	8.8	5.0	17.3	56.3
Iron	313.5	121.2	553.0	38.6	299.1	366.2	1,897.7	122.5
Lithium	0.2	0.1	0.4	57.9	4.0	5.7	18.0	140.1
Magnesium	142.7	30.9	151.8	21.6	266.6	191.2	851.1	71.7
Manganese	0.2	0.2	0.8	104.5	8.5	8.5	42.5	99.7
Potassium	2,219.5	797.4	3,302.4	35.9	256.0	138.5	880.8	54.1
Sodium	1,969.0	645.5	2,729.6	32.7	367.7	256.2	927.5	69.7
Strontium	0.4	0.3	1.3	69.8	8.1	7.9	32.7	97.0
Zinc	9.8	2.7	12.0	27.0	56.6	47.7	154.2	84.3

TABLE V. ELEMENT CONCENTRATIONS IN LIVER, KIDNEY AND BONE* OF THE DEER MOUSE (Peromyscus maniculatus) COLLECTED AT ROOSEVELT HOT SPRINGS (Values are given in µg/g wet weight for liver and kidney and in µg/g dry weight for the femur. Coefficient of variation is expressed as a percentage of the mean.)

	Liver (n = 56)				Kidney (n = 62)				Femur (n = 57)			
	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.
Barium	0.1	0.1	0.4	53.2	0.3	0.4	2.8	148.8	-	-	-	-
Boron	0.1	0.2	0.9	231.5	0.7	2.0	7.3	250.1	-	-	-	-
Cadmium	0.8	0.6	2.2	73.3	1.0	0.4	2.4	41.2	-	-	-	-
Chromium	**	-	-	-	0.1	0.3	1.2	298.7	-	-	-	-
Copper	12.0	6.3	25.1	52.2	12.4	6.0	19.8	47.9	-	-	-	-
Iron	161.4	63.1	346.9	39.1	143.5	70.6	325.9	49.2	-	-	-	-
Lead	0.1	0.3	1.5	387.3	0.3	0.9	5.8	303.4	4.9	7.7	34.5	156.5
Lithium	0.4	0.2	1.3	52.8	0.2	0.2	1.4	115.0	-	-	-	-
Magnesium	272.8	91.4	381.3	33.5	199.4	78.4	348.4	39.3	-	-	-	-
Manganese	2.4	1.1	5.5	47.3	1.9	0.9	3.6	49.8	-	-	-	-
Potassium	3,109.4	714.3	3,338.3	23.0	3,635.3	1,416.9	8,075.5	39.0	-	-	-	-
Sodium	1,609.1	384.6	1,473.7	23.9	1,731.1	713.9	2,601.4	41.2	-	-	-	-
Strontium	0.4	0.6	2.5	133.2	1.0	0.7	2.6	67.3	-	-	-	-
Zinc	19.1	6.1	24.6	32.2	23.4	8.1	37.1	34.7	-	-	-	-

* Femur analyzed for lead only.
** Trace (0.1 µg/g wet weight).

TABLE VI. ELEMENT CONCENTRATIONS IN LUNG AND HAIR OF THE DEER MOUSE (Peromyscus maniculatus) COLLECTED AT ROOSEVELT HOT SPRINGS (Values are given in µg/g wet weight for lung and in µg/g dry weight for hair. Coefficient of variation is expressed as a percentage of the mean.)

	Lung (n = 54)				Hair (n = 44)			
	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.
Arsenic*	-	-	-	-	**	-	-	-
Barium	0.1	0.1	0.7	84.7	3.2	3.5	13.0	110.5
Boron	0.1	0.2	0.9	240.1	7.0	13.9	79.6	198.8
Cadmium	0.7	0.5	2.0	71.2	0.7	1.6	5.6	228.8
Chromium	***	-	-	-	0.8	1.4	6.4	170.2
Copper	5.7	3.5	13.2	61.2	8.2	4.7	22.1	57.6
Iron	255.7	75.8	318.6	29.6	135.1	157.9	663.9	116.4
Lead	0.0	-	-	-	0.4	0.8	2.2	183.7
Lithium	0.2	0.2	1.0	103.7	2.4	3.6	10.2	149.6
Magnesium	217.8	101.2	677.2	46.5	297.0	128.5	462.7	43.3
Manganese	0.5	0.4	2.4	80.1	3.0	2.5	10.2	82.8
Potassium	3,539.6	1,321.9	6,149.8	37.3	220.6	62.8	416.2	28.5
Sodium	1,533.9	466.0	2,293.5	30.4	573.1	269.3	1,222.9	47.0
Strontium	0.4	0.5	2.5	110.5	6.1	5.0	20.7	83.0
Zinc	18.0	5.8	28.0	32.5	19.5	12.8	58.7	65.4

* Arsenic assays in hair only.
** Non-detectable, less than 10 ng/g dry weight (n = 16).
*** Trace (0.1 µg/g wet weight).

TABLE VII. ELEMENT CONCENTRATIONS IN LIVER AND KIDNEY OF THE GREAT BASIN POCKET MOUSE (Perognathus parvus) COLLECTED AT ROOSEVELT HOT SPRINGS (Values are given in µg/g wet weight. Coefficient of variation is expressed as a percentage of the mean.)

	Liver (n = 32)				Kidney (n = 41)			
	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.
Barium	0.5	0.5	2.0	117.2	0.8	1.1	6.0	143.3
Boron	1.6	3.3	12.7	206.2	3.7	5.5	21.2	147.4
Cadmium	0.4	0.4	1.3	98.6	0.6	0.5	1.6	85.5
Chromium	*	-	-	-	*	-	-	-
Copper	8.2	4.3	15.7	52.6	8.3	4.4	18.0	53.0
Iron	253.7	88.4	350.7	34.8	133.9	58.8	232.6	43.9
Lead	*	-	-	-	*	-	-	-
Lithium	0.2	0.1	0.4	57.3	0.4	0.2	0.9	57.5
Magnesium	245.8	63.4	304.3	25.8	247.6	119.9	560.3	48.5
Manganese	3.2	1.6	6.6	49.1	2.7	1.9	9.7	72.2
Potassium	3,054.7	756.4	3,420.2	24.8	3,133.0	1,079.6	4,025.0	34.5
Sodium	1,260.1	322.7	1,552.7	25.6	1,585.1	667.0	3,038.0	42.1
Strontium	0.7	0.6	2.3	78.9	1.0	1.0	4.0	98.5
Zinc	19.2	5.3	20.6	27.6	12.9	4.5	17.2	35.1

* Trace (0.01 - 0.4 µg/g wet weight).

TABLE VIII. ELEMENT CONCENTRATIONS IN LUNG AND HAIR OF THE GREAT BASIN POCKET MOUSE (Perognathus parvus) COLLECTED AT ROOSEVELT HOT SPRINGS (Values are given in µg/g wet weight for lung and in µg/g dry weight for hair. Coefficient of variation is expressed as a percentage of the mean.)

	Lung (n = 24)				Hair (n = 25)			
	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.
Arsenic*	-	-	-	-	**	-	-	-
Barium	0.2	0.2	0.9	114.7	11.4	14.2	58.6	124.7
Boron	0.1	0.1	1.3	85.7	12.3	11.0	33.1	89.8
Cadmium	0.5	0.4	1.2	80.3	1.8	2.7	6.9	145.3
Chromium	0.3	1.3	6.4	404.6	1.7	1.9	8.2	109.0
Copper	4.2	3.9	14.9	92.5	16.0	9.2	40.4	57.1
Iron	317.8	182.3	778.8	57.4	436.9	457.6	1,752.4	104.7
Lead	0.1	0.2	0.7	248.9	1.1	1.4	4.5	129.3
Lithium	0.2	0.1	0.4	63.2	3.6	5.0	20.8	141.3
Magnesium	239.5	81.2	380.9	33.9	280.3	223.3	931.2	80.0
Manganese	0.7	0.4	1.7	63.5	13.1	6.6	21.5	50.2
Potassium	2,829.3	770.2	2,934.8	27.2	409.4	284.7	1,136.5	69.5
Sodium	1,613.8	590.5	2,504.7	36.6	422.6	392.6	1,367.0	92.9
Strontium	0.6	1.3	6.6	222.3	7.0	6.7	28.3	96.4
Zinc	12.9	4.1	18.3	31.9	48.3	41.1	152.8	85.0

* Arsenic assays in hair only.
** Less than 10 ng/g (n = 15).

TABLE IX. ELEMENT CONCENTRATIONS IN LIVER AND KIDNEY OF THE PINYON MOUSE (Peromyscus truei) COLLECTED AT ROOSEVELT HOT SPRINGS (Values are given in µg/g wet weight. Coefficient of variation is expressed as a percentage of the mean.)

	Liver (n = 24)				Kidney (n = 24)			
	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.
Barium	0.1	0.1	0.3	58.9	0.1	0.1	0.2	48.3
Boron	0.1	0.2	0.9	180.1	0.1	0.1	0.6	105.3
Cadmium	0.6	0.4	1.2	70.0	1.2	0.5	2.4	41.6
Chromium	*	-	-	-	*	-	-	-
Copper	11.4	4.9	18.1	43.0	10.4	5.3	20.4	50.4
Iron	163.1	46.4	200.3	28.5	142.3	59.3	224.2	41.6
Lead	**				**			
Lithium	0.3	0.1	0.4	50.6	0.4	0.3	1.1	74.8
Magnesium	246.6	99.6	464.7	40.4	220.8	88.8	359.7	40.2
Manganese	2.3	0.9	3.5	40.3	1.9	0.7	2.7	39.7
Potassium	3,666.8	1,409.2	6,044.6	38.4	3,784.9	1,203.2	5,319.8	31.8
Sodium	1,566.3	512.2	1,865.8	32.7	2,052.6	786.2	2,996.0	38.3
Strontium	0.7	0.6	2.0	84.6	1.4	0.9	3.1	63.8
Zinc	23.1	7.6	27.0	32.9	22.2	6.6	34.0	29.6

* Trace (0.04 - 0.3 µg/g wet weight).
** Trace

TABLE X. ELEMENT CONCENTRATIONS IN LUNG, HAIR AND BONE* OF THE PINYON MOUSE (Peromyscus truei) COLLECTED AT ROOSEVELT HOT SPRINGS (Values are given in µg/g wet weight for lung and in µg/g dry weight for hair and femur. Coefficient of variation is expressed as a percentage of the mean.)

	Lung (n = 24)				Hair (n = 13)				Femur (n = 23)			
	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.
Arsenic†	-				‡				-			
Barium	0.1	0.0	2.0	51.2	0.9	0.8	2.1	89.1	-			
Boron	0.1	0.1	0.5	117.0	5.4	6.2	23.7	114.7	-			
Cadmium	0.7	0.6	1.8	86.3	§				-			
Chromium	#				0.2	0.1	0.4	99.2	-			
Copper	4.2	3.1	9.7	75.6	2.6	0.8	2.7	29.6	-			
Iron	298.5	116.4	430.7	39.0	91.6	100.6	269.8	109.9	-			
Lead	0.2	0.4	1.6	180.9	§				1.8	3.0	8.9	168.9
Lithium	0.1	0.1	0.3	113.6	8.4	13.4	49.8	158.6	-			
Magnesium	207.0	69.9	308.8	33.8	169.1	57.1	188.4	33.9	-			
Manganese	0.5	0.5	1.7	90.6	2.1	2.3	6.8	110.7	-			
Potassium	4,184.7	1,976.4	8,425.2	47.2	216.0	49.4	181.5	22.8	-			
Sodium	1,520.9	571.9	1,849.4	37.6	775.1	274.3	1,134.0	35.4	-			
Strontium	0.6	0.7	2.8	117.5	5.0	4.1	13.0	88.4	-			
Zinc	20.7	11.8	43.3	57.0	13.4	6.3	19.1	47.2	-			

* Lead analyzed in Femur samples only.
† Arsenic analyzed in hair only.
‡ Less than 10 ng/g dry weight (n = 11).
§ Non-detectable.
# Trace (0.04 µg/g wet weight).

TABLE XI. ELEMENT CONCENTRATIONS IN LIVER AND KIDNEY OF THE ORD'S KANGAROO RAT (Dipodomys ordii) COLLECTED AT ROOSEVELT HOT SPRINGS (Values are given in µg/g wet weight. Coefficient of variation is expressed as a percentage of the mean.)

	Liver (n = 13)				Kidney (n = 13)			
	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.
Barium	0.4	0.3	0.8	68.7	0.5	0.4	1.7	88.3
Boron	1.8	1.6	5.7	89.5	3.1	2.4	6.0	76.6
Cadmium	0.8	0.2	0.6	19.3	0.9	0.2	0.8	21.8
Chromium	0.1	0.1	0.4	215.5	0.1	0.2	0.5	179.4
Copper	11.8	2.8	10.0	23.4	12.9	2.6	11.1	20.3
Iron	325.1	206.0	805.5	63.6	127.4	39.1	164.4	30.7
Lead	*	-	-	-	**	-	-	-
Lithium	0.2	0.0	0.1	28.5	0.3	0.1	0.2	28.5
Magnesium	169.8	30.8	107.6	18.1	223.2	92.5	334.6	41.4
Manganese	2.4	1.0	2.7	40.6	1.9	0.8	3.4	45.3
Potassium	2,982.6	802.0	2,922.9	26.9	4,065.8	695.6	2,438.5	17.1
Sodium	1,207.9	207.0	755.5	17.1	1,481.4	274.2	980.0	18.2
Strontium	0.1	0.2	0.6	34.0	0.9	0.7	2.7	81.6
Zinc	23.9	7.3	24.0	30.5	19.3	5.0	17.3	25.7

* Trace (0.02 - 0.2 µg/g wet weight).
** Non-detectable

TABLE XII. ELEMENT CONCENTRATIONS IN LUNG AND HAIR OF THE ORD'S KANGAROO RAT (Dipodomys ordii) COLLECTED AT ROOSEVELT HOT SPRINGS (Values are given in µg/g wet weight for lung and in µg/g dry weight for hair. Coefficient of variation is expressed as a percentage of the mean.)

	Lung (n = 13)				Hair (n = 13)			
	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.
Barium	0.4	0.1	0.3	35.4	5.1	6.2	22.1	122.6
Boron	*	-	-	-	14.9	11.5	29.8	77.5
Cadmium	0.7	0.2	0.5	35.0	3.9	2.0	6.3	50.6
Chromium	0.4	0.8	1.5	200.0	1.9	2.3	8.1	119.7
Copper	6.3	0.8	1.8	11.9	15.8	4.9	19.0	30.8
Iron	374.8	155.6	286.2	41.5	275.7	256.4	781.2	93.0
Lead	*	-	-	-	2.6	1.8	5.5	69.3
Lithium	0.2	0.0	0.1	22.2	0.8	0.5	1.4	69.8
Magnesium	173.4	25.5	55.4	14.7	235.3	115.5	369.5	49.1
Manganese	0.3	0.2	0.3	46.2	8.5	12.3	44.5	143.2
Potassium	3,851.0	1,167.8	2,637.2	30.3	235.4	97.9	334.6	41.6
Sodium	1,349.9	200.1	419.8	14.8	207.9	172.4	452.4	82.9
Strontium	0.4	0.2	0.4	54.7	3.5	3.9	14.6	109.8
Zinc	13.5	3.1	7.2	23.1	101.9	54.8	170.5	53.8

* Non-detectable

TABLE XIII. ELEMENT CONCENTRATIONS IN LIVER AND KIDNEY OF THE WESTERN HARVEST MOUSE (Reithrodontomys megalotis) COLLECTED AT ROOSEVELT HOT SPRINGS (Values are given in µg/g wet weight. Coefficient of variation is expressed as a percentage of the mean.)

	Liver (n = 4)				Kidney (n = 4)			
	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.
Barium	0.5	0.4	0.9	81.3	0.6	0.3	0.6	47.1
Boron	*	-	-	-	0.1	0.2	0.4	200.0
Cadmium	0.8	0.5	0.1	6.5	1.1	0.7	1.6	67.7
Chromium	0.1	0.2	0.4	151.4	0.6	1.1	2.2	200.0
Copper	17.6	2.7	6.6	15.4	20.3	5.2	11.6	25.8
Iron	162.7	41.7	98.3	25.6	217.4	22.2	47.5	10.2
Lead	*	-	-	-	*	-	-	-
Lithium	0.1	0.0	0.0	0.0	0.6	0.6	1.2	93.6
Magnesium	219.3	53.9	111.5	24.6	351.6	222.4	509.8	62.3
Manganese	2.1	1.1	2.6	53.8	3.8	3.3	7.2	87.6
Potassium	3,428.8	529.5	1,285.9	15.4	5,243.5	1,531.2	3,467.9	29.2
Sodium	1,424.6	269.2	566.6	18.9	1,783.6	204.8	473.4	11.5
Strontium	0.6	0.4	0.7	59.3	1.2	1.0	2.1	80.8
Zinc	28.7	4.1	8.8	14.2	28.2	2.8	6.5	9.9

* Non-detectable

TABLE XIV. ELEMENT CONCENTRATIONS IN LUNG AND HAIR OF THE WESTERN HARVEST MOUSE (Reithrodontomys megalotis) COLLECTED AT ROOSEVELT HOT SPRINGS (Values are given in µg/g wet weight for lung and in µg/g dry weight for hair. Coefficient of variation is expressed as a percentage of the mean.)

	Lung (n = 4)				Hair (n = 4)			
	Mean	S.D.	Range	C.V.	Mean	S.D.	Range	C.V.
Barium	0.3	0.2	0.4	69.3	2.5	1.5	3.2	62.0
Boron	*	-	-	200.0	11.9	22.5	45.3	188.8
Cadmium	1.3	0.4	0.7	27.4	3.6	2.4	5.0	67.1
Chromium	0.1	0.1	0.1	115.5	0.2	0.2	0.4	127.7
Copper	8.7	2.7	6.1	31.3	4.6	0.9	2.1	20.5
Iron	305.0	80.8	184.4	26.5	94.7	56.5	137.4	59.6
Lead	0.4	0.8	1.6	200.0	**	-	-	-
Lithium	0.4	0.1	0.2	25.5	2.2	4.3	8.6	200.0
Magnesium	217.9	71.5	165.1	32.8	466.5	59.6	131.7	12.8
Manganese	0.7	0.3	0.6	38.7	2.2	1.2	3.0	55.8
Potassium	4,023.9	2,003.8	4,770.7	49.8	159.1	71.0	171.5	44.7
Sodium	1,572.7	387.1	815.9	24.6	473.8	119.9	273.9	25.3
Strontium	0.4	0.1	0.3	36.9	4.2	2.3	4.8	53.9
Zinc	26.6	13.8	29.2	51.8	19.1	2.0	4.7	10.4

* Trace (0.03 - 0.1 µg/g wet weight).
** Non-detectable

POPULATION CHARACTERISTICS

Mammalian species captured, sighted or thought to occur at Roosevelt Hot Springs are presented in Table XV. Habitat associations and food preferences (Table XVI) are also shown for those mammals collected or sighted in the geothermal resource area. The number of rodents captured per 100 trap nights is given in relation to the major KGRA habitats (Table XVII). These habitat designations are based on prevalent plant species and geographic location (elevation). Additional rodent population characteristics (ratios of (1) male to female, (2) adult to subadult and juvenile and (3) not reproductively active to reproductively active) for the three most prevalent species are given in Table XVIII. In Table XIX, biomass estimates are provided for Great Basin pocket mice, deer mice and the Ord's kangaroo rat.

In addition to this information, the Appendix contains eight tables which provide supporting and/or related information on the characteristics of small mammal populations at Roosevelt Hot Springs. Appendix Tables I, II, III, IV, V and VIII present the number of rodents captured and some additional rodent population characteristics (density, diversity, anatomical features and relative abundance). Appendix Table VI presents a gross estimate of relative abundance for lagomorphs (mainly the blacktailed jackrabbit) at sagebrush and sagebrush/pinyon-juniper communities. An indication of community similarity (Appendix Table VII) is also presented based on the presence or absence of various rodent species.

TABLE XV. SPECIES INCLUDED IN 1977-1978 ROOSEVELT HOT SPRINGS BASELINE ASSESSMENT AND OTHER MAMMALIAN SPECIES THOUGHT TO OCCUR IN THE GENERAL AREA

Primary Species Used for Current Baseline Assessment (1977-1978)	Pinyon mice (Peromyscus truei); Deer mice (Peromyscus maniculatus); Western harvest mice (Reithrodontomys megalotis); Ord's kangaroo rat (Dipodomys ordii); Great Basin pocket mice (Perognathus parvus); Blacktailed jackrabbit (Lepus californicus).
Additional Animals Sighted or Captured During Current Study (1977-1978)	Western big-eared bat (Plecotus townsendii); Nuttall's cottontail (Syviligus nuttalli); Desert cottontail (Syviligus audoboni); Least chipmunk (Eutamius minimus); Antelope ground squirrel (Ammospermophilus leucurus); Townsend's ground squirrel (Spermophilus townsendii); Rock squirrel (Spermophilus variegatus); Great Basin kangaroo rat (Dipodomys microps); Canyon mice (Peromyscus crinitus); Northern grasshopper mouse (Onychomys leucogaster); Desert woodrat (Neotoma lepida); Coyote (Canis latrans); Long-tailed weasel (Mustela frenata); Badger (Taxidea taxus); Mule deer (Odocoileus hemionus).
Additional Species Thought to Occur in General Area (Long, 1940; Fautin, 1946; Hall and Kelson, 1959; Armstrong, 1977)	Valley pocket gopher (Thomomys bottae); Northern pocket gopher (Thomomys talpoides); Utah prairie dog (Cynomys parvidens); Red squirrel (Tamiasciurus hudsonicus); Golden-mantled ground squirrel (Spermophilus lateralis); Cliff chipmunk (Eutamius dorsalis); Whitetailed jackrabbit (Lepus townsendii); Pygmy rabbit (Syviligus idahoensis); Brush mouse (Peromyscus boylii); Bushy-tailed woodrat (Neotoma cinerea); Mountain vole (Microtus montanus); Longtail vole (Microtus longicaudus); Sagebrush vole (Lagurus curtatus); Porcupine (Erethizon dorsatum); Kit fox (Vulpes macrotis); Black bear (Ursus americanus); Ringtail (Bassariscus astutus); Ermine (Mustela erminea); Western spotted skunk (Spilogale gracilis); Striped skunk (Mephitis mephitis); Bobcat (Lynx rufus); Mountain lion (Felis concolor); Wapiti (Cervis canadensis); Pronghorn (Antilocapra americana); Big free-tailed bat (Tadarida molossa); Mexican free-tailed bat (Tadarida brasiliensis); Pallid bat (Antrozous pallidus); Spotted bat (Euderma maculatum); Hoary bat (Lasiurus cinereus); Big brown bat (Eptesicus fuscus); Western pipistrelle (Pipistrellus hesperus); Silver-haired bat (Lasionycteris noctivagans); Small-footed myotis (Myotis subulatus); California myotis (Myotis californicus); Long-legged myotis (Myotis volans); Fringed myotis (Myotis thysanodes); Long-eared myotis (Myotis evotis); Little brown myotis (Myotis lucifugus); Dusky shrew (Sorex obscurus); Water shrew (Sorex palustris); Merriam's shrew (Sorex merriami); Vagrant shrew (Sorex vagrans).

TABLE XVI. HABITAT ASSOCIATIONS OF MAMMALS COLLECTED OR SIGHTED IN THE ROOSEVELT HOT SPRINGS KGRA VICINITY

Species	General Status	Habitat	Food Preference	Remarks
Sylviligus nuttalli Nuttall's Cottontail	uncommon	Higher sagebrush/ wooded areas	Green vegetation	Nocturnal; occurs at higher elevations than the Desert Cottontail. Game animal.
S. audoboni Desert Cottontail	uncommon	Low desert to pinyon-juniper	Sagebrush	Nocturnal. Game animal.
Lepus californicus Black-tailed Jackrabbit	common	Open sagebrush/ along roads	Sagebrush and green vegetation along roads	Does not burrow. Crepuscular and nocturnal.
Eutamius minimus Least Chipmunk	uncommon	Low sagebrush to coniferous forests	Mainly seeds and nuts; some animal matter	Diurnal; hibernates.
Ammospermophilus leucurus Antelope Ground Squirrel	common	Low desert to pinyon-juniper	Mainly seeds, some insects	Diurnal; active year round.
Spermophilus townsendii Townsend's Ground Squirrel	uncommon	Grassland; sage-brush; cultivated fields	Grasses, seeds, herbaceous plants	Colonial and distribution localized. Found only along banks of irrigation ditches. Hibernates and aestivates in late summer.

(continued)

TABLE XVI. HABITAT ASSOCIATIONS (Continued)

Species	General Status	Habitat	Food Preference	Remarks
S. variegatus Rock Squirrel	uncommon	Rocky slopes; higher elevations	Seeds, fruits, nuts, some animal matter	Hibernates; seen in study area only at highest elevations in pine associations.
Perognathus parvus Great Basin Pocket Mouse	abundant	Sagebrush to pinyon-juniper	Seeds	Hibernates; nocturnal; the dominant Heteromyid within the KGRA.
Dipodomys ordii Ord's Kangaroo Rat	common	Sandy soil, sparse vegetation	Mostly seeds, some green vegetation	Nocturnal; active year round, common in lower desert; uncommon at higher elevations in our study.
D. microps Great Basin Kangaroo Rat	rare	Associated with halophytic plants	Seeds and green vegetation	Nocturnal; in our study found only in saltbush associations.
Reithrodontomys megalotis Western Harvest Mouse	uncommon	Usually dense vegetation; near water	Mainly seeds; some vegetation and insects	Nocturnal; active year round. In current study found in greasewood and desert wash associations.
Peromyscus crinitus Canyon Mouse	rare	Rocky canyons; wide altitudinal range	Mainly seeds; some vegetation and insects	Nocturnal; active year round; found in arid areas.
Peromyscus maniculatus Deer Mouse	abundant	All habitats	Seeds, vegetation and animal matter	Nocturnal; active year round.

(continued)

TABLE XVI. HABITAT ASSOCIATIONS (Continued)

Species	General Status	Habitat	Food Preference	Remarks
P. truei Pinon Mouse	common	Rocky terrain in scattered pinyon-juniper	Seeds	Nocturnal; active year round.
Onychomys leucogaster Northern Grasshopper Mouse	rare	Arid to semiarid scrub deserts; sagebrush	Mostly animal matter, insects	Nocturnal; active year round: beneficial to man; utilizes burrows of other animals.
Neotoma lepida Desert Woodrat	uncommon	Desert floors to rocky slopes of higher elevations scattered sagebrush and pinyon-juniper	Vegetation; seeds	Nocturnal; active year round; homes above ground made of rubbish or along cliffs.
Canis latrans Coyote	uncommon	Throughout sage-brush and pinyon-juniper	Rodents and rabbits	Mainly nocturnal; a major predator.
Mustela frenata Longtail Weasel	rare	Low desert to mountain	Prefers pocket gophers; eats other small mammals	Utilizes old burrows of other animals.
Taxidea taxus Badger	rare	Open sagebrush and desert floors	Mainly rodents	Mainly nocturnal; digs out food.
Odocoileus hemionus Mule Deer	rare	Broken country; open plains, forests, seen only in pinyon-juniper and higher elevations	Browses on woody plants; also grasses	Important Game animal.

TABLE XVII. TRAP DAY INDEX (NUMBER OF ANIMALS CAPTURED PER 100 TRAP NIGHTS) AND THE SPECIES COMPOSITION OF RODENTS COLLECTED AT VARIOUS ROOSEVELT HOT SPRINGS HABITATS*

Habitat Designation	Animal Species	Trap Day Index	Percentage of Total Captures
Big Sagebrush (less than 1,585 m. elevation)	Dipodomys ordii	2.1	46.7
	Ammospermophilus leucurus	1.9	42.2
	Peromyscus maniculatus	0.5	11.1
Big Sagebrush (greater than 1,585 m. elevation)	Perognathus parvus	4.9	53.2
	Peromyscus maniculatus	3.7	40.2
	Dipodomys ordii	0.3	3.3
	Reithrodontomys megalotis	0.2	2.2
	Ammospermophilus leucurus	0.1	1.1
	Neotoma lepida	†	-
	Onychomys leucogaster	†	-
Pinyon - Juniper	Peromyscus maniculatus	2.2	68.8
	Peromyscus truei	0.6	18.8
	Perognathus parvus	0.4	12.5
Transition Zone (Big Sagebrush/ Pinyon-Juniper)	Perognathus parvus	5.1	65.4
	Peromyscus maniculatus	1.3	16.7
	Peromyscus truei	0.7	9.0
	Neotoma lepida	0.3	3.8
	Peromyscus crinitus	†	-
	Ammospermophilus leucurus	†	-
	Eutamius minimus	†	-
	Reithrodontomys megalotis	†	-
Greasewood	Peromyscus maniculatus	2.0	57.1
	Perognathus parvus	†	-
	Reithrodontomys megalotis	†	-
	Dipodomys microps	†	-
Wash Community #1 (Big Sagebrush/ Rabbitbrush/ Juniper)	Peromyscus truei	3.9	52.9
	Perognathus parvus	1.7	23.5
	Peromyscus maniculatus	0.9	11.7
	Reithrodontomys megalotis	†	-
	Dipodomys ordii	†	-
Wash Community #2 (Big Sagebrush/ Rabbitbrush)	Peromyscus maniculatus	5.9	65.5
	Reithrodontomys megalotis	1.3	14.8
	Dipodomys ordii	0.9	11.8
	Perognathus parvus	0.6	7.4
	Peromyscus truei	†	-

(continued)

TABLE XVII. TRAP DAY INDEX AND SPECIES COMPOSITION (Continued)

Habitat Designation	Animal Species	Trap Day Index	Percentage of Total Captures
Total of all Sampled Habitats at Roosevelt Hot Springs	Perognathus parvus	3.9	49.4
	Peromyscus maniculatus	2.8	35.4
	Peromyscus truei	0.4	5.1
	Dipodomys ordii	0.3	3.8
	Reithrodontomys megalotis	0.2	2.5
	Ammospermophilus leucurus	0.2	2.2
	All Others	†	-

* Seven habitat designations were chosen based primarily on prevalent plant species and geographic location (elevation). A single trap night refers to leaving one baited trap over night (one night) for potential rodent capture. Numerical values are presented in this table for the eleven rodent species collected at these RHS habitats. Ammospermophilus leucurus - Antelope ground squirrel; Dipodomys microps - Great Basin kangaroo rat; Dipodomys ordii - Ord's kangaroo rat; Eutamius minimus - Least chipmunk; Neotoma lepida - Desert woodrat; Onychomys leucogaster - Northern grasshopper mouse; Peromyscus crinitus - Canyon mice; Peromyscus maniculatus - Deer mice; Perognathus parvus - Great Basin pocket mice; Peromyscus truei - Pinyon mice; Reithrodontomys megalotis - Western harvest mice.

† Isolated captures.

TABLE XVIII. SEASONAL POPULATION CHARACTERISTICS FOR *Perognathus parvus*, *Peromyscus maniculatus* AND *Peromyscus truei* COLLECTED AT ROOSEVELT HOT SPRINGS DURING 1977 AND 1978 (Values are presented as ratios for M/F-male/female, A/SJ-adult/subadult and juvenile, NR/R-not reproductively active/reproductively active.)*

Month	*Perognathus parvus*			*Peromyscus maniculatus*			*Peronyscus truei*		
	M/F	A/SJ	NR/R	M/F	A/SJ	NR/R	M/F	A/SJ	NR/R
May	1.0/2.7	1.0/1.3	3.7/1.0	1.0/1.7	1.7/1.0	1.0/1.0	1.3/1.0	7.0/0.0	1.0/2.5
June	1.0/1.1	1.0/1.0	1.0/1.6	1.3/1.0	1.0/1.3	1.0/1.1	1.3/1.0	6.1/1.0	1.0/6.0
July	1.0/3.1	†	2.7/1.0	‡	‡	‡	1.0/1.5	5.0/0.0	1.0/4.0
August	0.0/35.0	1.0/4.0	34.0/1.0	1.0/2.1	1.0/1.8	21.0/1.0	1.0/1.5	5.0/0.0	4.0/1.0
September	1.0/1.3	1.0/2.5	7.0/0.0	1.8/1.0	1.8/1.0	1.8/1.0	‡	‡	‡
Total	1.0/2.3	1.0/1.8	1.9/1.0	1.0/1.2	1.1/1.0	1.5/1.0	1.0/1.0	23.0/1.0	1.0/2.0

* Characteristics are presented by month but represent a summary of all collections (live trap and snap trap) for the respective months from both 1977 and 1978. These three species (Great Basin pocket mice, deer mice and pinyon mice) were the only rodents to respectively comprise more than 5 percent of the total rodent captures.

† Data not collected.

‡ Species not collected.

TABLE XIX. BIOMASS ESTIMATES FOR THE RODENT POPULATION AT TWO ROOSEVELT HOT SPRINGS SAGEBRUSH COMMUNITIES (Values given as grams per hectare.)*

Trapping Period	Rodent Species†	Grid #1 Adjacent to Geothermal Well Site	Grid #2 Area Distant to Current Geothermal Activity
September 1977	Perognathus parvus	8.8	0.0
	Peromyscus maniculatus	12.9	24.8
May 1978	Perognathus parvus	0.0	20.9
	Peromyscus maniculatus	64.1	135.3
June 1978	Perognathus parvus	66.3	19.7
	Peromyscus maniculatus	5.2	103.0
	Dipodomys ordii	0.0	11.9
August 1978	Perognathus parvus	43.6	94.3
	Peromyscus maniculatus	22.6	65.8
	Dipodomys ordii	0.0	42.6

* Biomass calculated as mean weight of the species multiplied by the respective species density.

† Perognathus parvus - Great Basin pocket mice; Peromyscus maniculatus - Deer mice; Dipodomys ordii - Ord's kangaroo rat.

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APPENDIX A

SAMPLE PREPARATION FOR TRACE ELEMENT ANALYSIS BY ATOMIC ABSORPTION SPECTROSCOPY*

A. Laboratory Equipment, Reagents and Personnel.

1. Equipment

   a. Sample holding and storage containers (jars, bags, vials, etc.) should be made of polyethylene or a similar inert plastic.

   b. All other items used in sampling and sample handling (surgical instruments, spatulas, forceps, tongs, etc.) should be either Teflon-coated or made of plastic or stainless steel.

   c. Flasks or beakers used during microwave digestion should be made of Teflon or of a high-grade borosilicate glass. These containers should be used for either high- or low-level samples only, depending on previous use, and be so marked.

   d. Containers, flasks and instruments are cleaned prior to use. Wash in warm, detergent-supplemented water and rinse with deionized water. Soak for at least four hours in 1:1 conc. HNO_3/H_2O(V/V) or in 1:1:2 $HNO_3/HCL/H_2O$(V/V). Rinse with deionized water and oven dry at 50-60°C. Cover washed and dried equipment until needed.

   e. Dissecting tables are cleaned with dilute nitric acid and covered with disposable plastic lined pad. Fresh pads and gloves as well as fresh (cleaned) sets of instruments are used for each animal.

2. Reagents

   a. All water used must be deionized.

   b. Reagent impurity concentrations must be low enough that they do not interfere with elements of interest.

3. Personnel

   a. Persons involved in either washing operations or in tissue sampling will wear laboratory coats and sterile surgical gloves.

*Nelson, Z. C., W. W. Sutton, A. A. Mullen, W. F. Beckert and G. D. Potter. 1978. Procedures for Using Fauna as Biological Monitors of Potential Geothermal Pollutants. EPA-600/7-78-233. 31 pp.

b. All persons involved in sample digestion must wear rubber aprons, rubber gloves and safety glasses (or preferably safety masks).

c. Samples, glassware, instruments, etc., should never be touched with bare hands. Gloves are always worn and cleaned tongs or forceps are used. Smoking is not allowed in the laboratory.

d. All personnel involved in any aspect of sampling, sample handling, or sample preparation must be thoroughly familiar with the study procedures and objectives as well as difficulties associated with trace element work.

B. Tissue Collection, Preparation and Storage.

1. General Procedures

a. Clean, label, cap and weigh sample containers and assemble materials needed for dissection.

b. Perform dissection and place isolated tissues in respectively labeled containers. Cap and weigh containers recording net tissue wet weight.

c. Place open containers in drying oven (60°C) and dry to constant weights. Close containers, record sample dry weight and store containers (with sample) in freezer.

Note: Freeze drying is the preferred drying method as potential for contamination is usually reduced at lower temperatures. Freeze drying is used whenever equipment is available.

2. Procedures Applicable to Blood and Hair Samples.

a. The following procedure applies to blood samples.

(1) Samples are collected in sterile heparinized syringes (or vacutainer tubes) with sterile needles. Syringes are emptied into labeled, weighed polyethylene vials.

(2) Weighed samples are stored in the freezer.

b. The following procedure applies to hair samples. (Modified from Clarke and Wilson, 1974).

(1) To remove surface contamination, swirl hair sample (using forceps) in a hot detergent solution (10 ml commercial detergent in 600 ml of deionized water) and rinse in distilled water. Wrap sample in a 6 x 12" piece of cheesecloth, fold the ends over and secure them with white adhesive tape. Write identification number on the tape with an indelible marker.

(2) Slightly agitate the sample in deionized water and wring it out. Place sample in a hot detergent solution (10 ml detergent + 600 ml deionized water), squeeze it repeatedly with a glass rod and wring out.

Repeat step (2).

(3) Rinse sample in deionized water and wring it out. Place sample in acetone (300 ml), agitate and squeeze it repeatedly with a glass rod and then wring out.

(4) Place sample in 600 ml of a hot, filtered, saturated solution of ethylenediaminetetraacetic acid (EDTA) in deionized water, agitate and squeeze with a glass rod. After 5 minutes, remove and wring out the sample, wash sample twice in deionized water and wring out thoroughly.

(5) Dry sample at 60°C, open cheesecloth and transfer sample to a preweighed, labeled polyethylene container. Record net weight of clean hair sample and store in freezer.

C. Microwave Assisted Digestion of Biological Samples.

Note: Personnel conducting sample digestions must wear rubber gloves, apron and safety goggles or preferably safety masks. Accurate records of digestion steps are essential.

1. Sample Size

a. Sample size for microwave digestion should not exceed 1 g dry weight or, in the case of whole blood, should not exceed 5 g wet weight.

b. Samples should be treated with a minimum quantity of the purest acid available. Recommended nitric acid additions are 10 ml per 0.5 g of dry tissue or per 2.5 g of whole blood.

c. Volumetric flask size will be determined by initial sample size or requirements for replicate analyses.

2. Reagents

a. Concentrated nitric acid is transferred to a container (borosilicate) of convenient size and placed in hood.

b. Acid container labels must indicate preparation date and container contents. Do not allow dust to accumulate on the exterior of the container.

3. Digestion Procedure

a. Transfer approximately 0.5 g of dried tissue to a preweighed 100 ml Teflon beaker or to a 125 ml Erlenmeyer flask. Record tissue weight.

b. Add 10 ml conc. nitric acid to sample, swirl and allow to stand a few minutes (starts digestion).

c. Place beaker (containing sample) in microwave oven and turn switch to "high." When acid begins to boil, turn switch to "medium-low." As digestion progresses, digest color changes from dark to light; brown fumes are emitted. Digestion time is not critical, but is approximately one minute per ml of acid used. As digestion approaches completion, the solution should be clear or straw-colored and transparent. The digestion should be stopped when the solution volume is approximately 0.5 ml.

Note: If solution is not light colored and transparent more acid may need to be added and the digestion step repeated.

d. Turn switch to "off." When all fumes have been removed by exhaust system, open oven door, remove samples with tongs and cover sample beaker and transfer beaker to the hood for cooling.

e. Add 3-4 ml of deionized water to beaker, swirl and pour contents into volumetric flask. Rinse beaker with 2-3 ml of deionized water and add this to flask. Bring to volume with deionized water.

Note: If precipitate remains in flask, add HCl or another suitable solvent dropwise (not to exceed 5.0% of volume) until precipitate is dissolved. Water is then added to volume.

f. Transfer solution from volumetric flask to a polyethylene container for storage. Seal the labeled container and place it in the freezer.

D. Potential Errors During Sample Preparation and Storage.

1. Low Values

a. Incomplete sample digestion may result in incomplete solubilization.

b. Overheating of sample during digestion may result in partial volatilization of certain elements (e.g., mercury, arsenic).

c. Careless manipulation of samples and sample solutions may result in spillage.

d. Under certain conditions, elements of interest may be absorbed to container wall or to precipitates formed during digestion or storage.

e. During sample storage period, bacterial action may increase volatility of certain elements (e.g., formation of methyl mercury). This can be suppressed by freezing samples and keeping storage time to a minimum.

2. High Values

a. Use of less-than-clean laboratory equipment and use of impure reagents will produce inaccurate values.

b. Samples can also be contaminated by airborne dusts, mists and fumes.

c. Partial evaporation of water from improperly sealed digest containers will concentrate the solutes.

APPENDIX B

PREPARATION OF TISSUE SAMPLES FOR OPTICAL EMISSION SPECTROSCOPY ANALYSIS

Note: All equipment used in these procedures will have been thoroughly cleaned as was previously described.

1. Large samples (e.g., muscle) are isolated and dried as described earlier. The dried, frozen samples are homogenized (usually 2 to 3 minutes) in a Tekmar analytical grinding mill and part of the sample submitted for analysis.

2. Small samples (rodent organs) are isolated and dried as described earlier. Since the dry weight of these small organs is usually between 0.01 and 0.8 grams, each organ is cut into small pieces and the entire sample submitted for analysis.

3. Hair samples are washed as described, dried, cut into sections 4 to 5 mm long and submitted for analysis.

4. Blood samples are dried, then manually mixed wth a Teflon rod and submitted for analysis.

APPENDIX TABLE I. SUMMARY OF RODENTS COLLECTED AT ROOSEVELT HOT SPRINGS DURING BASELINE COLLECTION PERIOD (Number of captures shown for the various habitats are not directly comparable because of different trapping efforts.)

Habitat Designation	Animal Species	Number Collected
Big Sagebrush (less than 1,585 m. elevation)	Dipodomys ordii	8
	Ammospermophilus leucurus	7
	Peromyscus maniculatus	2
Big Sagebrush (greater than 1,585 m. elevation)	Perognathus parvus	174
	Peromyscus maniculatus	131
	Dipodomys ordii	11
	Reithrodontomys megalotis	7
	Ammospermophilus leucurus	4
	Neotoma lepida	1
	Onychomys leucogaster	1
Pinyon-Juniper	Peromyscus maniculatus	11
	Peromyscus truei	3
	Perognathus parvus	2
Transition Zone (Big Sagebrush/Pinyon-Juniper)	Perognathus parvus	88
	Peromyscus maniculatus	23
	Peromyscus truei	12
	Neotoma lepida	5
	Peromyscus crinitus	1
	Ammospermophilus leucurus	1
	Eutamius minimus	1
	Reithrodontomys megalotis	1
Saltbush	Peromyscus maniculatus	4
	Perognathus parvus	1
	Reithrodontomys megalotis	1
	Dipodomys microps	1
Wash Community #1 (Big Sagebrush/Rabbitbrush/ Juniper)	Peromyscus truei	9
	Perognathus parvus	4
	Peromyscus maniculatus	2
	Reithrodontomys megalotis	1
	Dipodomys ordii	1
Wash Community #2 (Big Sagebrush/Rabbitbrush)	Peromyscus maniculatus	19
	Reithrodontomys megalotis	4
	Dipodomys ordii	3
	Perognathus parvus	2
	Peromyscus truei	1

APPENDIX TABLE II. MEAN WEIGHT AND SELECTED MEAN MEASUREMENTS FOR THE THREE DOMINANT ROOSEVELT HOT SPRINGS RODENTS (Mean values and standard deviations are presented for adults only.)

Rodent Species	Sex	Number of Animals	Weight (g)	Total Length (mm)	Tail (mm)	Hind Foot (mm)	Ear (mm)
Perognathus parvus	male	6	22.4 ± 3.1	184.8 ± 9.6	96.0 ± 9.4	22.7 ± 1.0	8.5 ± 1.5
Perognathus parvus	female	7	20.8 ± 2.2	182.4 ± 11.5	94.0 ± 11.2	22.3 ± 0.9	8.4 ± 1.1
Peromyscus maniculatus	male	13	20.2 ± 2.0	158.6 ± 10.2	70.0 ± 10.5	20.2 ± 0.9	18.3 ± 3.9
Peromyscus maniculatus	female	17	20.4 ± 2.6	161.2 ± 9.9	68.9 ± 5.7	19.4 ± 0.9	16.4 ± 1.2
Peromyscus truei	male	12	23.8 ± 2.8	182.9 ± 8.6	86.9 ± 8.2	22.0 ± 1.0	23.7 ± 1.8
Peromyscus truei	female	11	20.5 ± 1.0	181.9 ± 9.7	86.1 ± 5.6	20.6 ± 1.1	23.9 ± 1.8

APPENDIX TABLE III. SUMMARY OF RODENT CAPTURES FROM TWO TRAPPING GRIDS LOCATED IN SAGEBRUSH COMMUNITIES AT ROOSEVELT HOT SPRINGS

Location	Rodent Species*	September 1977		May 1978		June 1978		August 1978	
		Total Marked	Total Captures	Total Marked	Total Captures	Total Marked	Total Captures	Total Marked	Total Captures
Grid I Adjacent to Geothermal Test Well	Perognathus parvus	2	4	6	9	17	34	19	46
	Peromyscus maniculatus	2	4	12	18	2	4	11	14
	Ammospermophilus leucurus	-	-	-	-	2	4	1	1
	Dipodomys ordii	-	-	-	-	1	1	-	-
	Onychomys leucogaster	-	-	-	-	-	-	1	1
	Reithrodontomys megalotis	-	-	-	-	-	-	1	1
Grid II Distance Control	Perognathus parvus	3	3	4	6	2	6	16	36
	Peromyscus maniculatus	4	8	18	34	18	35	12	29
	Dipodomys ordii	-	-	-	-	1	2	3	7
	Reithrodontomys megalotis	-	-	-	-	-	-	5	5

* Ammospermophilus leucurus - Antelope ground squirrel; Dipodomys ordii - Ord's kangaroo rat; Onychomys leucogaster - Northern grasshopper mouse; Peromyscus maniculatus - Deer mice; Perognathus parvus - Great Basin pocket mice; Reithrodontomys megalotis - Western harvest mice.

APPENDIX TABLE IV. RODENT DENSITY ESTIMATES FOR TWO ROOSEVELT HOT SPRINGS SAGEBRUSH COMMUNITIES (Values given as the number of animals per hectare.)

Trapping Period	Rodent Species*	Grid #1 Adjacent to Geothermal Well Site	Grid #2 Area Distant to Current Geothermal Activity
September 1977	Perognathus parvus	0.6	0.0
	Peromyscus maniculatus	0.6	1.4
May 1978	Perognathus parvus	0.0	1.3
	Peromyscus maniculatus	4.2	6.6
June 1978	Perognathus parvus	4.1	1.0
	Peromyscus maniculatus	0.3	6.3
	Dipodomys ordii	0.0	0.3
August 1978	Perognathus parvus	2.6	6.2
	Peromyscus maniculatus	1.6	4.2
	Dipodomys ordii	0.0	1.0

* Perognathus parvus - Great Basin pocket mice; Peromyscus maniculatus - Deer mice; Dipodomys ordii - Ord's kangaroo rat.

APPENDIX TABLE V. CALCULATIONS ON SPECIES DIVERSITY FOR RODENTS AT VARIOUS ROOSEVELT HOT SPRINGS HABITATS

Habitat Designations	Diversity Expressions*		
	H'	H max	J'
Transition Zone (Big Sagebrush/Pinyon-Juniper)	1.026	1.946	0.527
Big Sagebrush	0.982	1.946	0.504
Wash Community #1 (Big Sagebrush/Rabbitbrush/ Juniper)	1.266	1.610	0.786
Wash Community #2 (Big Sagebrush/Rabbitbrush)	1.079	1.610	0.670
Saltbush	1.154	1.386	0.832
Pinyon - Juniper	0.832	1.099	0.757
Total of all Sampled Habitats at Roosevelt Hot Springs	1.265	2.398	0.528

* Diversity calculations include H' which represents a relative diversity and H max which is the maximum possible diversity (Shannon and Weaver, 1963). J' represents the relationship between relative diversity and maximum diversity - the maximum value for J' would be 1.0 (Pielou, 1966; Lloyd et al., 1968).

APPENDIX TABLE VI. GROSS ESTIMATE OF RELATIVE ABUNDANCE FOR LAGOMORPHS AT TWO AREAS OF ROOSEVELT HOT SPRINGS*

Date		Location†	
		Area Adjacent to Geothermal Development	Area Distant to Geothermal Development
1977	June	3.3	‡
	July	1.1	2.3
	September	0.0	1.0
1978	May	0.9	1.2
	June	5.4	0.6
	August	3.1	2.1

* Values given as the number of lagomorphs (mainly the black-tailed jackrabbit-Lepus californicus) sighted per kilometer traveled. Census counts were taken shortly after dark.

† Both census areas were predominantly sagebrush or sagebrush/pinyon-juniper communities.

‡ No data.

APPENDIX TABLE VII. SIMILARITY BETWEEN COMMUNITIES BASED ON PRESENCE OR ABSENCE OF VARIOUS RODENT SPECIES (Degree of similarity expressed as a percentage.)*

	Low Big Sagebrush	Big Sagebrush	Pinyon-Juniper	Transition Zone	Saltbush	Wash #1	Wash #2
Low Big Sagebrush	-	60.0	33.0	54.5	28.6	50.0	50.0
Big Sagebrush	-	-	40.0	67.0	54.5	67.0	67.0
Pinyon-Juniper	-	-	-	54.5	57.1	75.0	50.0
Transition Zone	-	-	-	-	50.0	61.5	61.5
Saltbush	-	-	-	-	-	67.0	67.0
Wash #1	-	-	-	-	-	-	100.0
Wash #2	-	-	-	-	-	-	-

* Meullen - Dombois and Ellenberg, 1974
Transition Zone (Big Sagebrush/Pinyon-Juniper)
Wash #1 (Big Sagebrush/Rabbitbrush/Juniper)
Wash #2 (Big Sagebrush/Rabbitbrush)

APPENDIX TABLE VIII. ESTIMATES OF RELATIVE ABUNDANCE FOR RODENT SPECIES FROM TWO TRAPPING GRIDS LOCATED IN SAGEBRUSH COMMUNITIES AT ROOSEVELT HOT SPRINGS*

Trapping Period	Rodent Species	Grid I Adjacent to Geothermal Test Well			Grid II Distance Control		
		Hayne†	EM-2‡	Lincoln§	Hayne†	EM-2‡	Lincoln§
September 1977	Perognathus parvus	1.5	2.0	2.0	0.0	0.0	0.0
	Peromyscus maniculatus	2.0	2.0	2.0	4.2	4.0	4.0
May 1978	Perognathus parvus	0.0	0.0	2.0	3.3	2.0	4.0
	Peromyscus maniculatus	13.2	8.8	10.0	20.5	21.6	19.5
June 1978	Perognathus parvus	10.9	11.9	11.2	2.7	3.9	2.0
	Peromyscus maniculatus	1.0	2.0	1.0	19.5	19.0	20.2
	Ammospermophilus leucurus	0.0	0.0	1.0	#	#	#
	Dipodomys ordii	0.0	0.0	0.0	1.0	1.0	1.0
August 1978	Perognathus parvus	6.8	7.2	7.9	16.5	18.1	18.2
	Peromyscus maniculatus	4.9	3.1	5.0	13.1	11.5	12.2
	Ammospermophilus leucurus	0.0	0.0	0.0	#	#	#
	Dipodomys ordii	#	#	#	3.0	3.0	3.0
	Onychomys leucogaster	0.0	0.0	0.0	#	#	#
	Reithrodontomys megalotis	0.0	0.0	0.0	0.0	0.0	0.0

* All computations were based on the same trapping effort (at least three consecutive trap nights) using a mark-recapture technique.

† Hayne, D. W. 1949. J. Mammal. 30:399-411.

‡ Communiction from Woodward-Clyde Consultants on analysis of original census data using stochastic population model.

§ Lincoln, F. C. 1930. Dept. Agriculture Cir. 118:1-4.

No animals captured.